WINTERING MULE DEER PREFERENCE FOR 21 ACCESSIONS OF BIG SAGEBRUSH

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ABSTRACT.—Wintering mule deer showed differential browsing preference among 21 accessions of big sagebrush (*Artemisia tridentata*) grown on gardens on three different mule deer herd ranges. The Hobble Creek accession of big sagebrush was significantly preferred over the other 20 accessions across all three sites and for all three years. Accessional preference means for the study period for all sites combined ranged from 28.3 to 57.5%. The data collected support the planned release of the Hobble Creek accession as a superior cultivar of big sagebrush for use on mule deer winter ranges. Plant coumarin content was primarily under genetic control, but site factors also had an effect. Assay for coumarin compounds is useful in determining subspecies of *A. tridentata* but not for precise prediction of mule deer browsing preference.

During in vivo digestion trials Smith (1950) observed that mule deer showed definite aversion to individual big sagebrush (*Artemisia tridentata*) plants. Since then several field workers have observed differential preference of wintering mule deer not only for individual plants but also for populations of big sagebrush (Plummer et al. 1968, Winward 1970, Brunner 1972, Hanks et al. 1973, Stevens and McArthur 1974, Winward and Tisdale 1977, McArthur et al. 1979, Willms et al. 1979). We reported (Welch et al. 1981) that wintering mule deer showed differential preference for 10 accessions of big sagebrush grown on a uniform garden. This study is an effort to include 11 more accessions (21 total), different sites, different mule deer herds, and the role of coumarin compounds in the preference of wintering mule deer for accessions of big sagebrush. Coumarin compounds have been shown to be positively correlated with mule deer preference of some sagebrush taxa (Stevens and McArthur 1974).

MATERIALS AND METHODS

Three outplanting sites were selected within the elevational range of most Utah mule deer winter ranges (1,370–2,140 m): Springville, Utah; 3 km east of Nephi, Utah (Salt Creek Canyon); and 15 km west/southwest of Helper, Utah (Gordon Creek Wildlife Management Area).

The Springville site at 1,402 m is a basin big sagebrush habitat type. Soil is of the Pleasant Grove series (Pleasant Grove gravelly loam, 6–10% slope), consisting of deep, well-drained, gravelly or cobbley soils, alluvial fans. Weathered limestone is the parent material. Soil permeability is moderately rapid. Roots can penetrate to a depth of 1.5 m or more. About 9 cm of available water is held by this soil to a depth of 1.5 m. Soil pH ranges from 7.4 to 7.9. Average annual precipitation is 35–45 cm. The mean annual temperature is 8.9–11.1 C, and the frost-free period is 150–170 days (Swenson et al. 1972).

The Salt Creek Canyon site (1,676 m) is a basin big sagebrush habitat type. Soil is a Rofiss gravelly clay loam 4–15% slope. It is a deep, well-drained alluvial soil. Parent material is Arpien shale. Soil permeability is moderately slow. Effective rooting depth is 1.5 m or more. Soil pH ranges from 8.2 to 8.6. Average annual precipitation is 20–35 cm. The mean annual temperature is 7.2–8.3 C, and the frost-free period is 100–120 days (Soil Conservation Service 1980).

The Gordon Creek Wildlife Management Area, at 2,130 m, is a Wyoming big sagebrush habitat type. Soil is of the Atrac series (Atrac is a very fine sandy loam 1–6% slopes). This series consists of deep, well-drained soils. Parent material is sandstone. Effective rooting depth is 1.5 m or more. Soil pH ranges

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TABLE 1. Locations of collection sites for 21 accessions of big sagebrush (*Artemisia tridentata*) used in this study to determine wintering mule deer preference.

Subspecies	Accession	County and state	Elevation (m)
vaseyana	Colton	Utah, Utah	2,260
	Sardine Canyon	Cache, Utah	1,800
	Benmore	Tooele, Utah	1,900
	Petty Bishop's Log	Sanpete, Utah	2,380
	Durkee Springs	Sevier, Utah	2,270
	Salina Canyon	Sevier, Utah	2,350
	Clear Creek Canyon	Sevier, Utah	2,130
	Pinto Canyon	Washington, Utah	1,850
	Indian Peaks	Beaver, Utah	2,140
	Hobble Creek	Utah, Utah	1,500
tridentata	Clear Creek Canyon	Sevier, Utah	1,720
	Brush Creek	Uintah, Utah	1,830
	Loa	Wayne, Utah	2,140
	Dove Creek	Dolores, Colorado	2,070
	Evanston	Uinta, Wyoming	2,020
	Wingate Mesa	San Juan, Utah	2,060
	Dog Valley	Juab, Utah	1,700
wyomingensis	Evanston	Uinta, Wyoming	2,130
	Kaibab	Coconino, Arizona	2,340
	Trough Springs	Humboldt, Nevada	1,400
	Milford	Beaver, Utah	1,540

from 6.6 to 8.0. Average annual precipitation is 30.5–35.6 cm. The mean annual temperature is 7.2–8.3 C, and the frost-free period is 100–120 days (Soil Conservation Service 1981).

At each site the vegetation was killed by disking and kept weed free by hand and mechanical means. Deer-proof fences were built around each site. We planted each site in spring 1978 with containerized stock of 21 accessions of big sagebrush (Table 1). Each accession was represented by 10 plants, and each plant was an experimental unit within the accessions. The resulting 210 plants in each set were placed at random on a 3 x 3 m grid for each site. Table 1 lists the locations of seed collection sites for the accessions.

We measured the preference for the accessions by randomly selecting 15 annual leaders per plant through the entire crown and measuring them to the nearest centimeter in November 1980, 1981, and 1982. These measurements were used to calculate a mean annual leader length per plant before browsing. We remeasured plants using 15 randomly selected leaders during April 1981, 1982, and 1983 and calculated a mean annual leader length after browsing. Percentage used or preference was calculated by dividing the mean leader length after browsing by the mean leader length before browsing, multiplying by 100, and subtracting from 100. Welch et al. (1981) reported a precision error of 4% for this method. Data were expressed as percentage used (preference).

Ultraviolet visable, fluorescent, water-soluble coumarin compounds (principally isoscopoletin, scopoletin, and esculetin) were measured by placing leaf fragments from single leaves (5 samples/plant) of approximately 1 mg size in water in cuvettes (McArthur et al. 1981). We used 1 mg leaf material/0.3 ml water up to 10 mg leaf material/sample. After 90 minutes equilibration time, spectrophotometric readings (percent transmittance) were made at 364 nm in a Bausch and Lomb Spectronic 700 spectrophotometer. Leaves for coumarin analysis were collected at the time of the 1983 preference measurements.

The three subspecies of big sagebrush, *A. t.* ssp. *tridentata*, *vaseyana*, and *wyomingensis*, were represented in this study. Of the 21 accessions, 10 were *vaseyana*, 7 were *tridentata*, and 4 were *wyomingensis*. This gave the capability of testing for subspecies effects on preference.

Analyses were performed using the SPSS^x statistical package (SPSS Inc., 1983). We used analysis of variance techniques, Student-Newman-Keuls multiple range mean com-

TABLE 2. Effects of subspecies, site, and year on preference of wintering mule deer for accessions of big sagebrush (*Artemisia tridentata*). Data expressed as percent of current year's growth eaten (3 years, 630 plants, three gardens).

	Preference for subspecies	
A. t. ssp. *tridentata*	*A. t.* ssp. *wyomingensis*	*A. t.* ssp. *vaseyana*
32.6[a*]	35.3[b]	44.1[c]
	Effects due to site	
Salt Creek	Gordon Creek	Springville
30.4[a*]	35.0[b]	50.2[c]
	Effects due to years	
1980	1981	1982
31.6[a*]	41.7[b]	42.4[b]

*Means sharing the same superscript are not significantly different at the 5% level.

TABLE 3. Preference of wintering mule deer for accessions of big sagebrush (*Artemisia tridentata*) grown on different gardens. Data expressed as a percent of current year's growth eaten. Data points for gardens represent a three-year mean.

	Garden			
Accession	Gordon Creek	Salt Creek	Springville	Mean
Evanston (t)**	25.2	18.1	41.6	28.3[a*]
Trough Springs (w)	17.5	30.9	41.9	30.1[ab]
Dove Creek (t)	26.3	31.3	35.1	30.9[abc]
Clear Creek Canyon (t)	31.5	19.7	42.7	31.3[abcd]
Loa (t)	25.0	18.5	51.3	31.6[abcd]
Kaibab (w)	30.9	27.2	42.4	33.5[abcd]
Dog Valley (t)	28.6	23.6	49.1	33.8[abcde]
Brush Creek (t)	35.2	24.6	47.2	35.7[abcde]
Wingate Mesa (t)	32.5	33.9	42.8	36.4[abcdef]
Milford (w)	34.9	29.0	47.4	37.1[bcdefg]
Clear Creek Canyon (v)	34.4	25.6	55.1	38.4[bcdefg]
Benmore (v)	40.1	39.3	38.4	39.3[bcdefg]
Pinto Canyon (v)	36.8	27.8	56.2	40.3[cdefg]
Evanston (w)	31.1	43.8	46.3	40.4[defg]
Durkee Springs (v)	36.3	27.7	58.1	40.7[defg]
Salina Canyon (v)	40.5	29.4	55.2	41.7[efg]
Sardine Canyon (v)	45.8	29.9	58.0	44.6[fg]
Indian Peaks (v)	40.9	40.9	55.0	45.6[fg]
Petty Bishop's Log (v)	46.4	33.8	57.7	46.0[g]
Colton (v)	43.1	37.9	60.1	47.0[g]
Hobble Creek (v)	52.0	47.4	73.0	57.5[h]

*Means sharing the same superscript are not significantly different at the 5 % level.
**t = *A. t.* ssp. *tridentata*; v = *A. t.* ssp. *vaseyana*; w = *A. t.* ssp. *wyomingensis*.

parison tests, and regression techniques. Data collected as percent were transformed by the arcsin percentage function for analysis and then returned to the percent values for final presentation (Snedecor and Cochran 1956).

RESULTS AND DISCUSSION

The overall mean percent of leader length used for all years, sites, and accessions was 38.6%. Two three-way analyses of variance detected significant effects due to all main effects of year, site, subspecies, and accession (Table 2).

Wintering mule deer significantly preferred the subspecies *A. t.* ssp. *vaseyana* over *A. t.* ssp. *wyomingensis* and *A. t.* ssp. *tridentata* (Table 2). They significantly preferred *A. t.* ssp. *wyomingensis* over *A. t.* ssp. *tridentata*. These results agree with reports of previous studies (Stevens and McArthur 1974, Welch et al. 1981).

Significantly more big sagebrush was consumed by wintering mule deer at the Springville site than at Salt Creek and Gordon Creek (Table 2). Big sagebrush consumption was significantly more at Gordon Creek than at Salt Creek. This differential use among the sites strengthens our ability to rank the pref-

TABLE 4. Analysis of variance of amount of coumarin by subspecies and effects due to site. Data are presented as percent transmittance (364 mm)*.

Amount of coumarin by subspecies*		
A. t. ssp. *tridentata*	*A. t.* ssp. *wyomingensis*	*A. t.* ssp. *vaseyana*
61.9^{a**}	54.7^{b}	37.7^{c}
Effects due to site**		
Salt Creek	Gordon Creek	Springville
43.6^{a***}	48.6^{b}	57.9^{c}

*Percent transmittance is an inverse function of coumarin content.
**Means sharing the same superscript are not significantly different at the 5% level.
***Springville site differences were compounded by disproportionate mortality of ssp. *vaseyana* prior to 1983 at that site.

TABLE 5. Linear regression comparisons of mean preference and percent transmittance values.*

Comparison	Number of pairs	r	Significance
All accessions	21	− 0.58	.01
Subspecies	3	− 0.998	.05
A. t. ssp. *tridentata*	7	− 0.75	ca. .05
A. t. ssp. *wyomingensis*	4	+ 0.82	NS
A. t. ssp. *vaseyana*	11	+ 0.01	NS

*Values computed from Tables 2 and 4 using mean values only (Snedecor and Cochran 1956). Percent transmittance is an inverse function of coumarin content.

erence of mule deer for the accessions of big sagebrush. Also, different mule deer herds occupied the three sites, thus eliminating any confounding resulting from previous exposure to a given type of big sagebrush.

Significantly more big sagebrush was consumed during 1981 and 1982 than in 1980 (Table 2). We have no explanation for these differences.

Wintering mule deer significantly preferred the Hobble Creek accession over the other 20 accessions across all sites and years (Table 3). Overall use of the Hobble Creek accession was 57.5%. Use of Hobble Creek big sagebrush varied significantly between sites. At the Salt Creek site, the Hobble Creek accession received 47.4% use, 52.0% use at Gordon Creek, and 73.0% use at Springville. The consistency of ranking for preference of the Hobble Creek accessions was not present for the other accessions and further strengthens our contention that the Hobble Creek is the most preferred. This consistency was also true for years. These study results agree with our earlier study (Welch et al. 1981). We are currently collecting data needed to support the release of Hobble Creek through the Soil Conservation Service plant development program as a superior cultivar of big sagebrush for use on mule deer winter ranges.

Different levels of coumarin compounds were found to be present in each subspecies (Tables 4 and 5). Earlier studies have shown that ssp. *vaseyana* had higher coumarin levels than ssp. *tridentata* and *wyomingensis* (Stevens and McArthur 1974, McArthur et al. 1981). In a previous report, we suggested that these coumarin compounds would be useful for indirect selection for preference (Welch and McArthur 1979). This study shows that there is an environmental component to coumarin content (Table 4). The effects due to site are significant. Nevertheless, genetic factors are of overriding importance. Subspecies were significantly different in coumarin content (Tables 4 and 5), and individual accessions ranked rather consistently in coumarin content across sites (Table 6). Coumarin content data from a set of plants over three years and all seasons showed that, whereas coumarin levels may vary temporally, individual plants maintain general positions in respect to other plants in the population (McArthur, Welch, and Noller, data on file, Shrub Sciences Laboratory).

Coumarin compounds are useful indicators of *A. tridentata* subspecies—especially in distinguishing ssp. *vaseyana* from ssp. *tridentata* and *wyomingensis* (Stevens and McArthur 1974, McArthur et al. 1981, Table 4). Their use as preference indicators for browsing

TABLE 6. Percent transmittance at 364 nm by accession and site. Mean preference* is also given.

Accession	Mean preference	Percent transmittance			
		Gordon Creek	Salt Creek	Springville	Mean
Dove Creek (t)**	30.9	63.0	62.9	72.9	66.1[a***]
Clear Creek Canyon (t)	31.3	66.9	57.2	68.6	63.9[ab]
Evanston (t)	28.3	57.0	63.8	69.0	63.4[ab]
Dog Valley (t)	33.8	67.7	58.4	63.7	63.3[ab]
Loa (t)	31.6	63.4	58.0	67.5	62.8[ab]
Evanston (w)	40.4	67.2	56.9	52.6	59.3[abc]
Wingate Mesa (t)	36.4	58.2	53.9	64.5	58.9[abc]
Brush Creek (t)	35.7	64.3	49.3	49.0	54.6[bcd]
Milford (w)	37.1	57.5	46.8	57.1	53.7[bcd]
Pinto Canyon (v)	40.3	49.4	49.4	63.2	53.7[bcd]
Trough Springs (w)	30.1	57.7	50.0	51.5	53.0[bcd]
Kaibab (w)	33.5	49.1	51.9	53.5	52.6[bcd]
Hobble Creek (v)	57.5	49.5	45.3	56.5	49.5[cd]
Colton (v)	47.0	47.3	40.8	48.2	45.5[d]
Indian Peaks (v)	45.6	46.1	41.4	53.1	34.2[d]
Durkee Springs (v)	40.7	44.2	37.1	57.4	45.0[d]
Clear Creek Canyon (v)	38.4	29.1	26.0	53.0	33.1[e]
Sardine Canyon (v)	44.6	23.4	22.6	55.0	31.6[e]
Salina Canyon (v)	41.7	21.7	28.4	48.2	31.2[e]
Benmore (v)	39.3	26.0	16.8	43.5	27.1[e]
Petty Bishop's Log (v)	46.0	16.4	13.4	****	14.8[f]

*From Table 3.
**t = *A. t.* ssp. *tridentata*; v = *A. t.* ssp. *vaseyana*; w = *A. t.* ssp. *wyomingensis*.
***Means sharing the same superscript are not significantly different at the 5% level.
****No surviving plants in 1983.

mule deer is examined in Tables 5 and 6. We concluded that these compounds are good general indicators in the sense that the subspecies are browsed differentially by mule deer (Table 2), and those differences are reflected by differences in coumarin content (Table 4). The relationship is ssp. *vaseyana* > ssp. *wyomingensis* > ssp. *tridentata* in browsing preference and in coumarin content. However, the relationship of coumarin content to browsing preference is not strong nor consistent within subspecies (Tables 5 and 6). A regression analysis (SPSS^x) interacting all (n=573) coumarin and preference data points gave an unimpressive but highly significant ($p < .001$) r^2 of 0.06. Linear regression values were strikingly different in magnitude and sign for the three subspecies (Table 5). Furthermore, an examination of the data for the most preferred accession, Hobble Creek (ssp. *vaseyana*), shows that it has a relatively low coumarin content for its subspecies (Table 6). Coumarin content is useful in identifying preferred taxa but not in making distinctions within those taxa.

The chromosome number level may impact coumarin content. Most ssp. *tridentata* and *vaseyana* accessions are diploid. The *wyomingensis* accessions are tetraploid (McArthur et al. 1981, McArthur and Welch 1982). Both tetraploid spp. *tridentata* accessions (Wingate Mesa and Brush Creek) are relatively high in coumarin content (Table 6). Two of the ssp. *vaseyana* accessions with relatively low coumarin content (Colton and Pinto Canyon) are tetraploid. The additional genomes may be responsible for a moderating effect in the case of tetraploids for both ssp. *tridentata* and *vaseyana*. Tetraploid plants of both subspecies move toward intermediate values from the more extreme values of their respective diploids.

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